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HOW COOPETITION AFFECTS KNOWLEDGE RECOMBINANT CAPABILITIES: TOWARD A NETWORK PERSPECTIVE

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INTRODUCTION

Coopetition refers to the simultaneous cooperation and competition between firms within the same industry (Brandenburger and Nalebuff, 2011; Gnyawali et al., 2006; Gnyawali and Madhavan, 2001; Tsai, 2002). Extant coopetition research has mainly considered the direct ties between competitors, pointing to their value creation opportunities as well as their value appropriation risks (Gnyawali and Park, 2009). In this paper, we refer to the collection of direct ties with competitors as the *direct coopetition network* of a focal firm. At the same time, engaging in collaboration with a competitor also implies the generation of indirect ties with the competitors of this latter actor. In this paper, we define the collection of indirect ties between the focal firm and other firms in the same industry as the focal firm's *indirect coopetition network*.

Focusing on the direct coopetition network, extant coopetition research (e.g. Dussauge et al., 2000; Estrada et al., 2016; Gnyawali and Park, 2011) has provided valuable insights into how the composition of this network influences the ability of the focal firm to recombine knowledge. At the same time, however, this research stream has ignored the potential impact of the indirect coopetition network. This is surprising as the broader knowledge network theory (Ahuja, 2000; Burt, 2004, 2009; Ghosh and Rosenkopf, 2014; Phelps et al., 2012) provides strong indications that not only the direct connections of focal actors, but also their indirect connections can substantially influence a focal firm's knowledge recombination activities. The core objective of this study is therefore to analyze the impact of both the direct and indirect coopetition network on the *knowledge recombining capabilities* (i.e., the ability of the focal firm to generate novel recombination of knowledge).

Knowledge network theorists also stress that, next to the external network structure, knowledge recombination is shaped by the internal network structure of focal firms (Katila, 2002; Nerkar and Paruchuri, 2005; Phelps et al., 2012). In this study, we therefore explicitly consider the moderating impact of firms' internal network on the relationships between direct/indirect coopetition networks and focal firms' knowledge recombining capabilities. Specifically, we consider focal firms' internal collaboration network and internal technology network. Internal *collaboration network* (CN) refers to the social network of collaboration between inventors, whereas internal *technology network* (TN) comprises all linkages between knowledge elements (Wang et al., 2014; Yayavaram and Ahuja, 2008).

To test our hypotheses, we construct a large-scale panel data set from 323 global solar photovoltaic (PV) firms between 1995 and 2015. To construct external coopetition and internal

networks, we gather data from multiple archival sources (i.e., LexisNexis, SDC, Orbis, Compustat and PATSTAT databases).

THEORY AND HYPOTHESES

In the spirit of the recombination view of the firm, achieving and sustaining a competitive advantage critically depends on the firm's ability to recombine different kinds of knowledge to break those bonds and produce novel ideas. Many scholars have pointed to coopetition between two directly competing firms as a viable strategy to foster the recombination of complementary knowledge and thus stimulate the development of innovation (Dussauge et al., 2000; Estrada et al., 2016; Gnyawali and Park, 2011). The resources from coopetitors are particularly critical since competitors often have the most relevant and valuable resources as they face similar environmental and competitive challenges (Gnyawali and Park, 2009). Yet, coopetition can also be a conduit of direct knowledge spillover (Bouncken et al., 2015). Coopetitors have both the motivation and the ability to absorb valuable knowledge from each other, triggering risks of knowledge spillovers, which in-turn impedes the process of knowledge recombination (Cassiman et al., 2009). Hence, coopetition triggers both value creation opportunities and value appropriation risks.

However, coopetition scholars have mainly emphasized the value creation and appropriation of a firm with its direct coopetitors. We, instead, highlight the broader network in which the coopetition relationships are embedded: indirect coopetition networks. From this perspective, value creation and appropriation process not only happen in interaction with direct coopetitors, but also are manifested in *n*-order ties to other firms.

Coopetition networks and knowledge recombinant capabilities

Direct coopetition network and knowledge recombinant capabilities. From a value creation perspective, direct coopetition facilitates knowledge recombination through generating access to complementary information (Ahuja, 2000; Estrada et al., 2016; Gnyawali and Park, 2009). The larger the number of direct ties with coopetitors, the higher the potential to get access to external knowledge containing novel recombinant opportunities (Nerkar, 2003). However, as the number of direct ties with coopetitors increases, the marginal benefits for knowledge recombinant capabilities are likely to decrease. In particular, a excessive number of coopetitors provides many unfamiliar streams of knowledge, which may exceed the focal firm's absorptive capacity and make recombinant search costs grow exponentially (Ahuja and Katila, 2004; Dong et al., 2017; Paruchuri, 2010).

From a value appropriation perspective, the increasing number of direct ties with coopetitors poses threats in terms of knowledge recombination. More extensive collaboration with coopetitors may trigger significant value appropriation risk in knowledge recombination, such as unintended information spillovers or free riding behaviors (Estrada et al., 2016; Hamel, 1991). Following recent guidance of curvilinear theorizing (Haans et al., 2016), we formulate the following hypothesis based on the above mechanisms.

Hypothesis 1 (H1): The size of a firm's direct coopetition network has an inverted U-shaped relationship with its knowledge recombinant capabilities.

Indirect coopetition network and knowledge recombinant capabilities. We argue that the size of the indirect coopetition network has a negative impact on focal firms' knowledge recombinant capabilities. As the size of the indirect coopetition network increases, the focal firm's direct coopetitors may take advantage of the size of the indirect coopetition network to increase its bargaining power in value appropriation (Ozmel et al., 2017). Specifically, direct coopetitors can obtain more bargaining power as it controls knowledge exchange and leakage from the focal firm to other firms in the indirect coopetition network, which therefore limits the focal firm's capabilities in acquiring and recombining knowledge from direct coopetitors. Meantime, because of the greater bargaining power of direct coopetitors, the focal firm is confronted with more knowledge spillover risks and less information spill-into benefits from coopetitors. In addition, information that a focal firm receives from coopetitors may be highly distorted during the transfer process (Guan and Liu, 2016). As a result, the focal firm has to spend much more effort and time in detecting and eliminating the distorted knowledge (Hill, 1990; Russo et al., 2000). We therefore hypothesize:

Hypothesis 2 (H2): The size of a firm's indirect coopetition network has a negative relationship with its knowledge recombinant capabilities.

The moderating roles of internal networks

The moderating role of internal CN with a small-world structure. We argue that the small-worldliness of internal CN moderates the inverted U-shaped relationship between direct coopetition network and knowledge recombinant capabilities. The small-world structure of internal CN refers to the presence of dense clusters of local contacts linked by occasional nonlocal contacts whereby any inventor in the network can easily reach other inventors (Fleming et al., 2007). In such a collaborative structure inventors can easily reach other inventors within the firm through a relatively small number of intermediaries, providing them with timely access to complementary knowledge from other inventors (Phelps et al., 2012). This small-world structure of internal CN facilitates the generation of trust and reciprocity among inventors (Phelps, 2010), which increase their joint problem-solving efforts and stimulate knowledge recombination. Prior literature has shown a substitution relationship between the use of external sources and internal R&D activities (Grigoriou and Rothaermel, 2017). Because combining internal and external information exert significant pressure on the firm manager's limited attentional capability (Ocasio, 1997), the firms that already have the capabilities to internally recombine knowledge to create novel ideas rely less on external knowledge (Grigoriou and Rothaermel, 2017). Furthermore, the value appropriation risk brought by coopetitors, such as unintended information spillovers or free riding behaviors, will significantly decrease. Thus, we have the following hypothesis.

Hypothesis 3a (H3a): A firm's internal CN small-world Q moderates the inverted U-shaped relationship between direct coopetition network and knowledge recombinant capabilities such that the inverted U-shape is flattening and the turning point moves right when internal CN small-world Q increases.

As internal CN small-worldliness increases, the focal firm has stronger capabilities to internally recombine knowledge. The interactions with external cooeptitors are therefore less

attractive for new knowledge creation, decreasing the coopetitors' information control and bargaining power resulting from the indirect coopetition network. As a result, the focal firm faces less value appropriation risks. We therefore have the following hypothesis.

Hypothesis 3b (H3b): As a firm's internal CN small-world Q increases, the relationship between indirect coopetition network and knowledge recombinant capabilities becomes less negative.

The moderating role of internal KN with a small-world structure. Small-worldliness of internal TN may also moderate the inverted U-shaped relationship between direct coopetition network and knowledge recombinant capabilities. The value creation benefits of direct collaboration with competitors are strengthened when TN small-worldliness is high. The TN small-worldliness can be defined as clusters of locally dense connected knowledge elements via a few bridging ties (Fleming et al., 2007), which enable local recombinant search to coexist with distant recombinant search. When the complementary knowledge from coopetitors flows into focal firms, with high TN small-worldliness, they can conduct recombinant search quickly and efficiently (Fleming, 2001; Schilling and Green, 2011). In addition, the value appropriation risk of direct coopetition ties is amplified when TN small-worldliness is high. The high relatedness between knowledge elements increases a firm's knowledge spillover to other firms, especially its core information. We therefore hypothesize.

Hypothesis 4a (H4a): A firm's internal TN small-world Q moderates the inverted U-shaped relationship between direct coopetition network and knowledge recombinant capabilities, such that the inverted U-shape is steepening and the turning point moves left when internal TN small-world Q increases.

As the number of indirect ties with other firms in the industry increase, the focal firm is confronted with more knowledge spillover risk and less information spill-into benefits for knowledge recombination. When the knowledge elements in the focal firm are highly related, the situation is worse because its core knowledge can easily spill-out. Therefore, we have the following hypothesis.

Hypothesis 4b (H4b): As the firm's internal TN small-world Q increases, the negative relationship between indirect coopetition network and knowledge recombinant capabilities is strengthened.

METHODOLOGY

Data

To test our hypotheses, we constructed a large-scale panel data set from global solar photovoltaic (PV) firms between 1995 and 2015. The solar PV industry is high-technology, innovation-intensive, and characterized by cooperation between competitors, providing us an ideal empirical setting to test our hypotheses (Kapoor and Furr, 2015; Wu and Mathews, 2012). Our data were gathered from five archival sources. Using *LexisNexis*, we obtained 57,689 pieces of alliance news in the solar PV industry. We manually coded all the news and got 1115 solar PV

alliances in the time period 1995-2015. Finally, we matched these alliances with SDC database and obtained 1210 unique alliances. We matched each firm with a unique BVD ID in the Orbis database. Our competition data was from the *Orbis* database, which divides all firms into 20 major sectors (e.g., machinery, agriculture, banks, chemicals, electricity, etc.). In this study, we considered two allying firms as coopetitors if they belong to the same major sector. Finally, we constructed the coopetition network based on a five-year time window and obtained 2,582 firm-year level observations. We obtained patent data from the European Patent Office's (EPO) *PATSTAT* database. We used the application date to assign each patent to a focal firm. We collected 36,459 patents filed by our sampled firms. Financial data were collected from the Standard and Poor's *Compustat* database and *Orbis* database.

Measures

Knowledge recombining capabilities. Our measure of knowledge recombining capabilities is consistent with Carnabuci and Operti (2013) by taking into account the number of new combinations and total combinations. Specifically, based on patent data, we computed the share of subclass co-assignments that had not been used by the focal firm in the prior five years.

Direct and indirect coopetition networks. To measure the direct coopetition network, we counted the number of direct coopetitors of the focal firm. Following Ahuja (2000), we measure the size of the indirect coopetition network as follows:

$$\text{Indirect coopetition network} = \sum_i^m \left(\sum_k P_j \right) \left(1 - \frac{f_i}{N+1} \right), \quad (1)$$

f_i is the total number of coopetitors that can be reached up to and including the path distance and $\sum_k P_j$ means the number of patents belonging to the coopetitors within distance i .

Internal collaboration and technology networks. Small world Q offers a unique combination of high local clustering and low global average path length. We built the internal collaboration network (CN) among inventors for each firm in a five-year time window. Following previous research (Gulati et al., 2012), we calculated the small-world quotient as follows:

$$Q_{CN} = \alpha (C/C_R) / \beta (L/L_R), \quad (2)$$

where $\alpha = 1/N$, $\beta = \ln(N)$ (N means the number of inventors). C_R and L_R indicate the clustering coefficients and the global average path length of random collaboration network with same nodes and ties. Similarly, based on co-occurrence of IPC codes of patents, we built internal technology networks (TN) for each firm in each period (Wang et al., 2014) and calculated the internal technology network Q in a similar way.

Control variables. R&D intensity, patent stock, knowledge recombining stock, technological diversity, largest component of network, technological overlap between a focal firm and its coopetitors, market overlap between a focal firm and its coopetitors, geographical overlap between a focal firm and its coopetitors, non-coopetition alliances, firm size, and firm age are controlled in our empirical analysis.

RESULTS

We test our hypotheses with a firm fixed effects model to better control for time-invariant

unobservable firm characteristics. Our results provide support for H1-H4a, but not for H4b. We also conducted several robust checks, including Tobit models, random effects model, winsorization for knowledge recombinant capabilities, endogeneity test by using merger and acquisition (M&A) rumor and nearby rivals' alliance partners as instrumental variables (Ryu et al., 2017), and assessment of sample selection bias by using a Heckman model with exclusion restriction (nearby rivals' alliance partners) (Ozmel et al., 2017). We found that our results are robust.

DISCUSSION AND CONCLUSION

This study makes three major contributions to the coopetition literature. First, we make a clear distinction between direct and indirect coopetition networks and therefore contribute a more holistic network perspective to coopetition research. Extant coopetition research only considered the direct ties between coopetitors (i.e., direct coopetition network). However, they ignore the potential impacts of indirect connections between a focal firm and other firms from the same industry in the network (i.e., indirect coopetition network). Drawing on the knowledge network theory, we advance coopetition research by comparing the impacts of direct and indirect coopetition networks on knowledge recombinant capabilities of focal firms. We find the size of a focal firm's direct coopetition network has an inverted U-shaped effect on its knowledge recombinant capabilities, while the size of a focal firm's indirect coopetition network negatively affects its knowledge recombinant capabilities.

Second, we propose that a focal firm's internal network structures interact with external coopetition networks when influencing its knowledge recombinant capabilities. We show that the impact of direct and indirect coopetition networks on knowledge recombinant capabilities vary depending on the structure of internal collaboration and technology networks, adding another layer in understanding coopetition. Specifically, we study how the internal collaboration networks (CN) and technological networks (TN) shape the contingency of the effectiveness of external value creation with coopetitors and mitigate the risk of value appropriation. Interestingly, we find that a small-world structure of CN and TN exerts contradictory moderating effects on the relationships between direct and indirect coopetition networks and knowledge recombinant capabilities.

Finally, this study opens a new avenue of inquiry that offers considerable promise in explaining knowledge recombinant capabilities. By connecting with complementary research streams on coopetition network (Gnyawali et al., 2006), multi-level network (Grigoriou and Rothaermel, 2017; Paruchuri, 2010) and knowledge recombination search (Carnabuci and Operti, 2013; Fleming, 2001), it helps us understand the causal forces that underlie knowledge recombinant capabilities.

REFERENCES AVAILABLE FROM THE AUTHORS

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